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Evolution from analog T/R Module to 5G Antenna System and their Measuring methods

Prosund Technology

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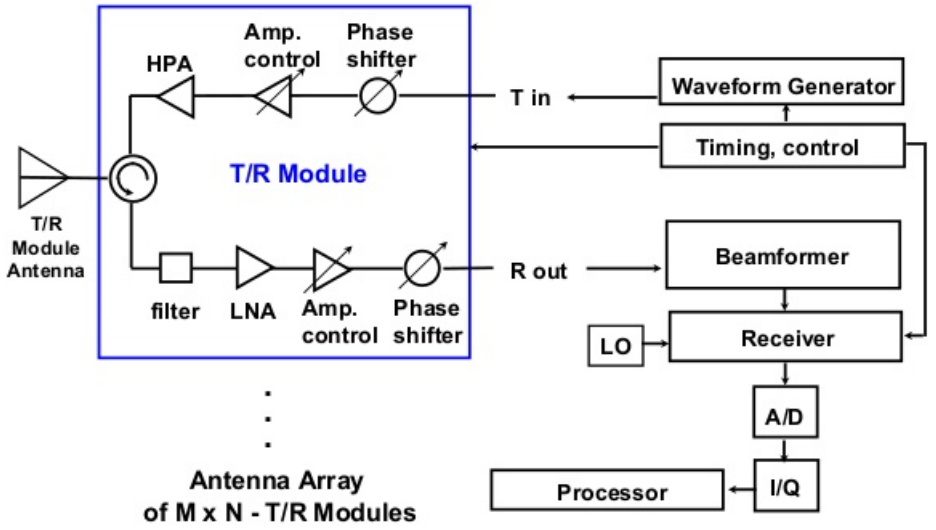
Content

Overview of TRM

Intro：

- **T/R-modules are key elements in active phased array antennas for radar and electronic warfare applications**
- **A T/R module is a multichip assembly of solid state device based sub-system**
- **Each module contains filtering, amplification and amp./phase control**
- **Main functions:**
  - Power amplification during transmission
  - Phase shift and attenuation control
  - Low noise amplification during receive
  - Transmit/receive switching
  - Discrete control and status monitoring
  - Establishing communication with beam steering network and facilitating proper supply voltages

Block Diagram of Active Radar Array using T/R Modules



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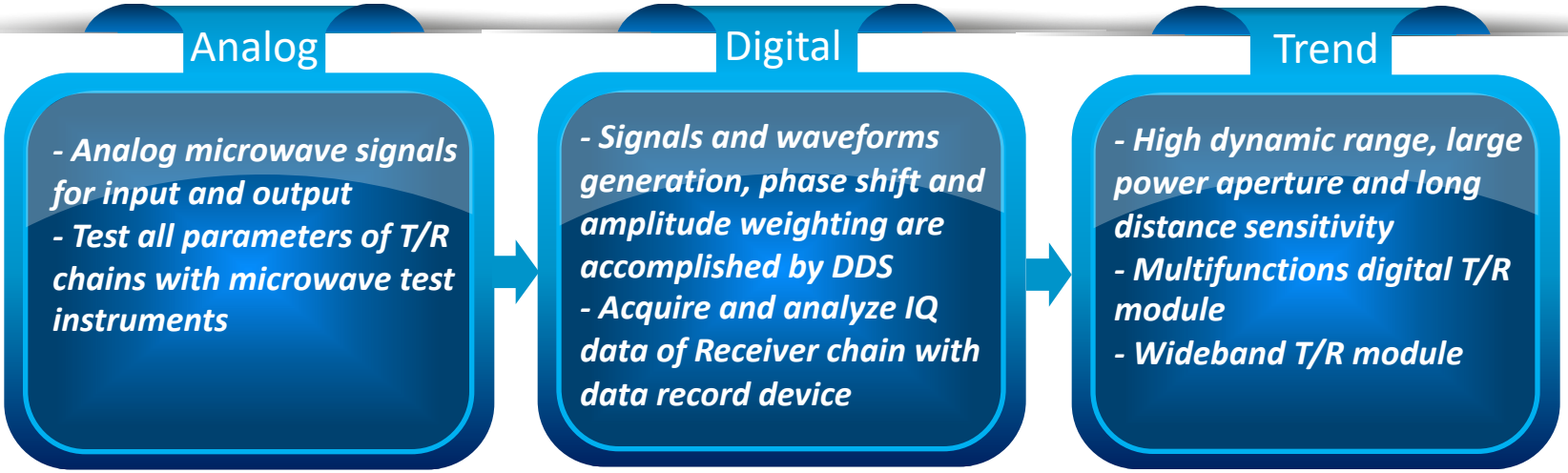
Overview of TRM

History and Evolutionary Trends：

From the perspective of system configuration



From the perspective of semiconductor technology

Parameters	1st generation	2nd generation	3rd generation
Power amplifier technology	Si BJT	Si LDMOS	GaN HEMT
Max Pulse width	100us	200us	200us
Duty cycle	10%(max)	20%(max)	20%(max)
Power drop	0.8dB(max)	0.6dB(max)	0.6dB(max)
Pulse fall/rise time	200ns	100ns	100ns

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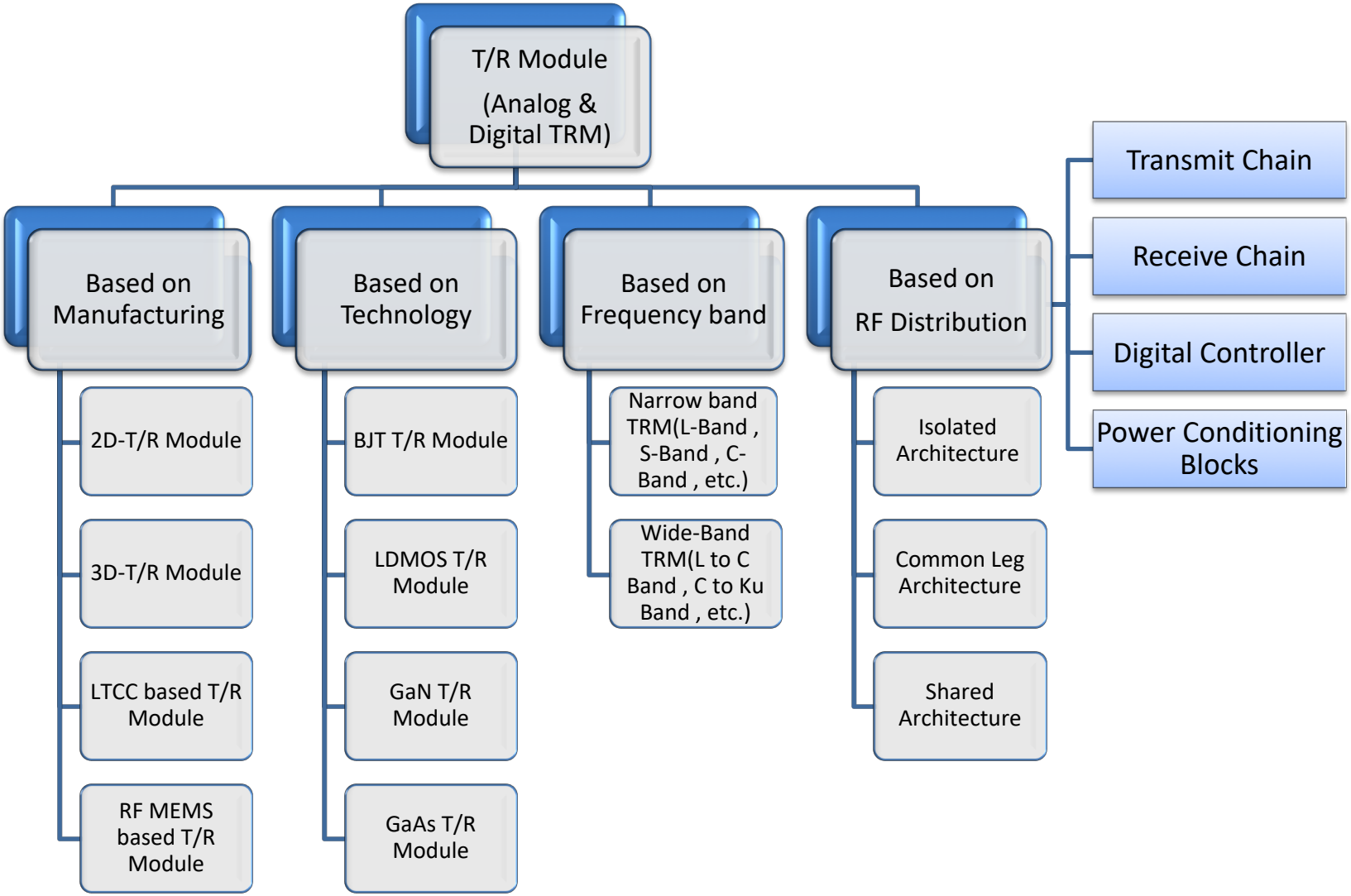
Overview of TRM

Taxonomy of T/R module：



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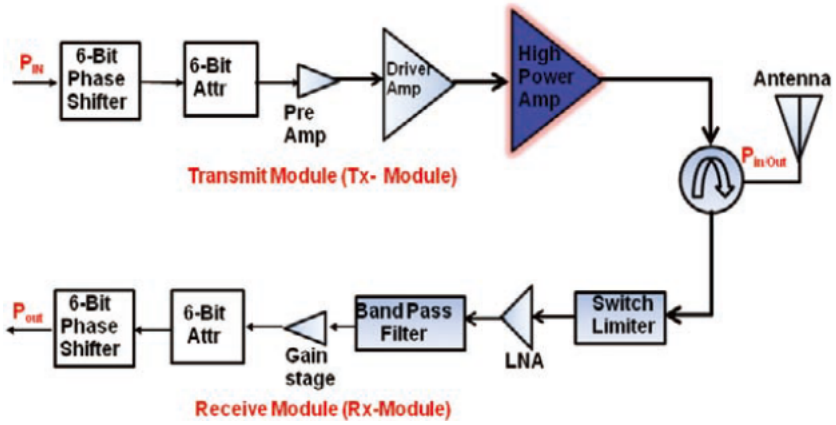
Overview of TRM

Taxonomy of T/R module：

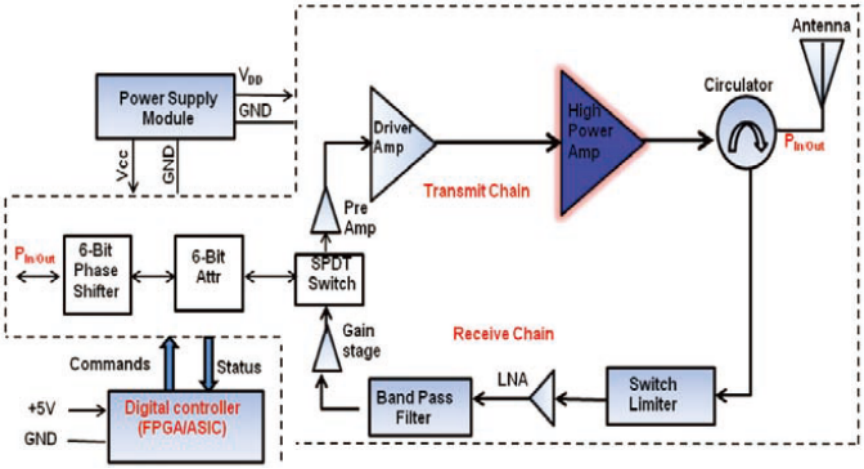
➢ Isolated Architecture



Main Characters:

- Earliest architecture
- Separate phase shifter and attenuator for each Tx and Rx channel
- Best performance, but with increased complexity and system cost

➢ Common Leg (Shared) Architecture



Main Characters:

- The most popular architecture
- The phase shifter and attenuator are used in the common leg circuit
- Switch Common leg for Tx/Rx chain by SPDT switch and digital controller
- Increased level of integration and lowered system cost

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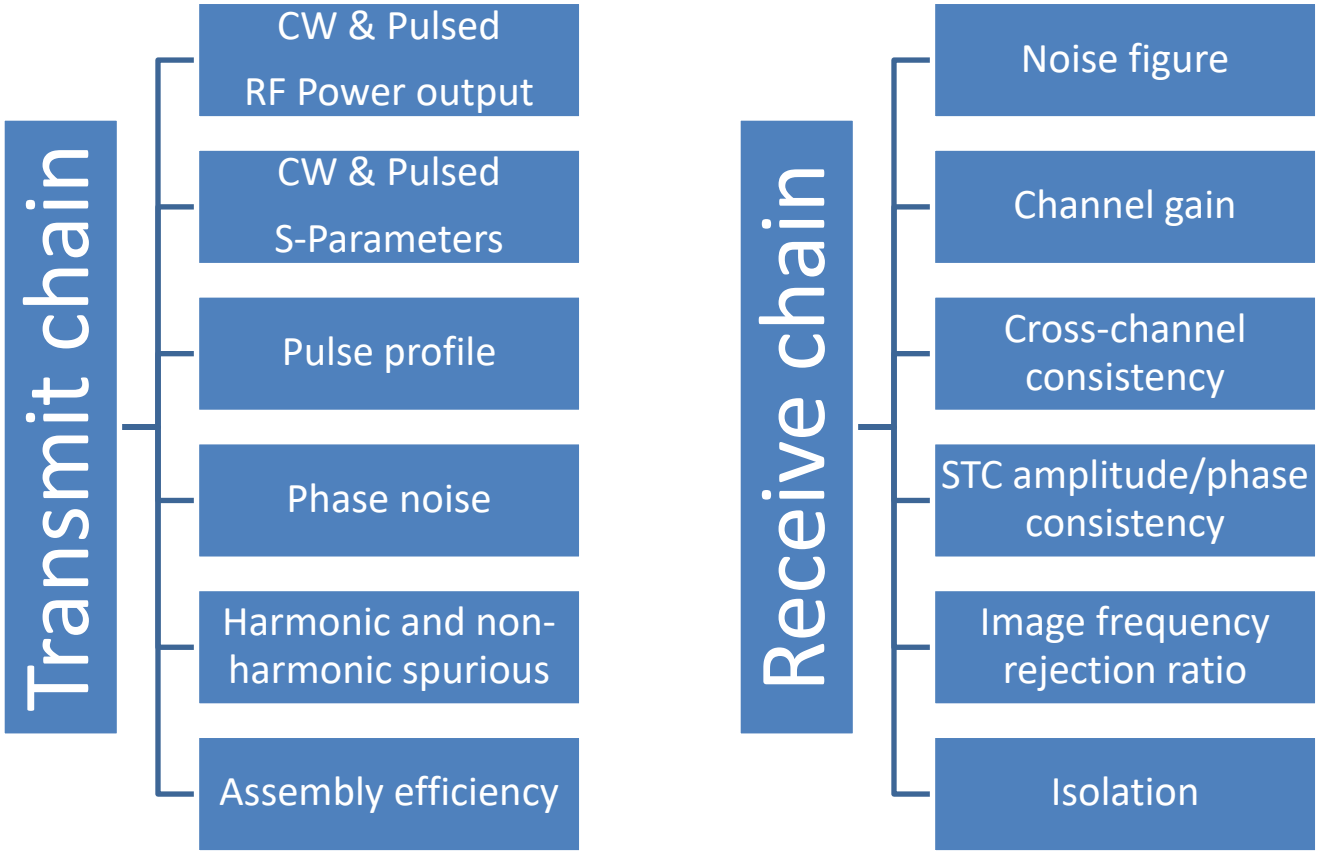
Test of TRM

Test of Digital T/R module：

- Test parameters



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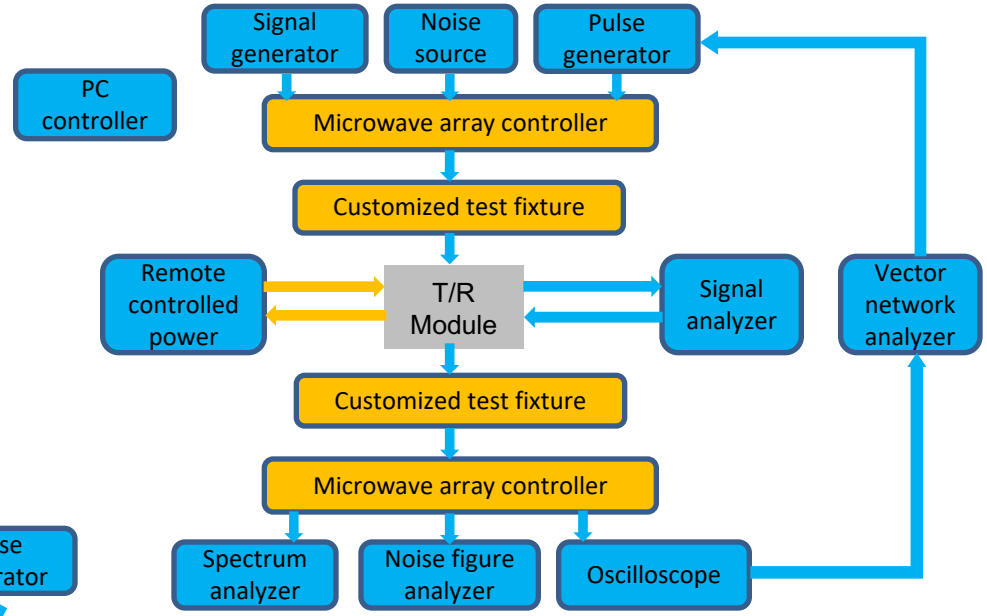
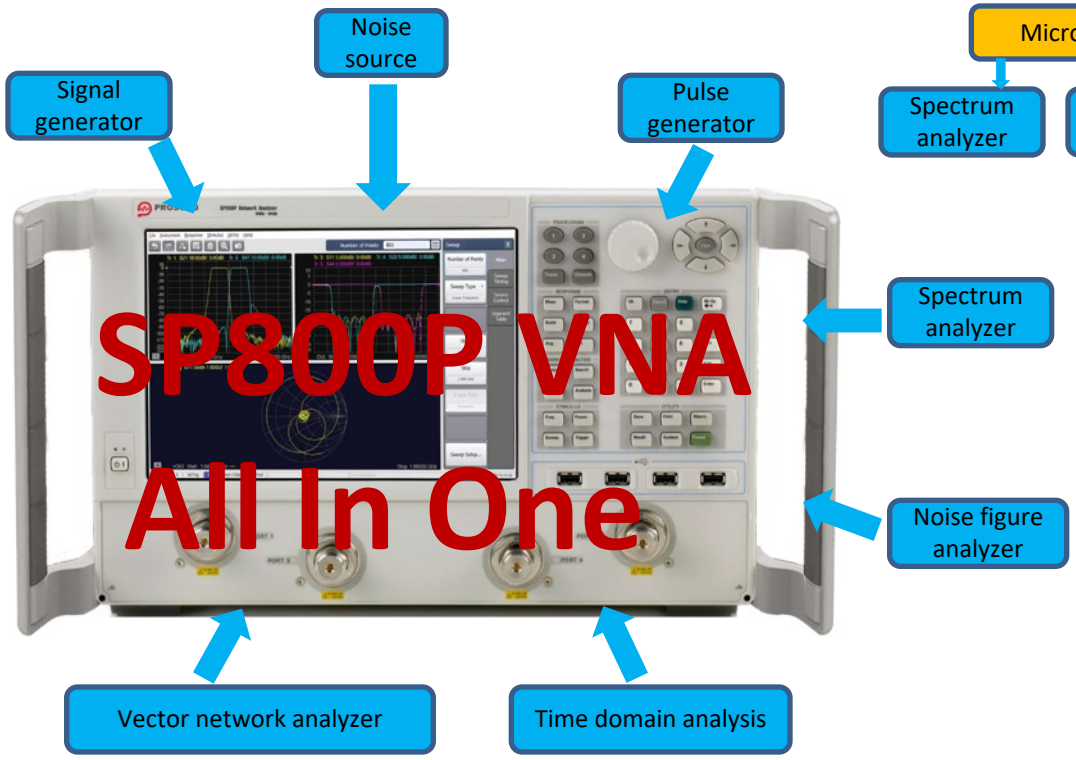
Test of TRM

Test of Digital T/R module：

➢ Test system architecture





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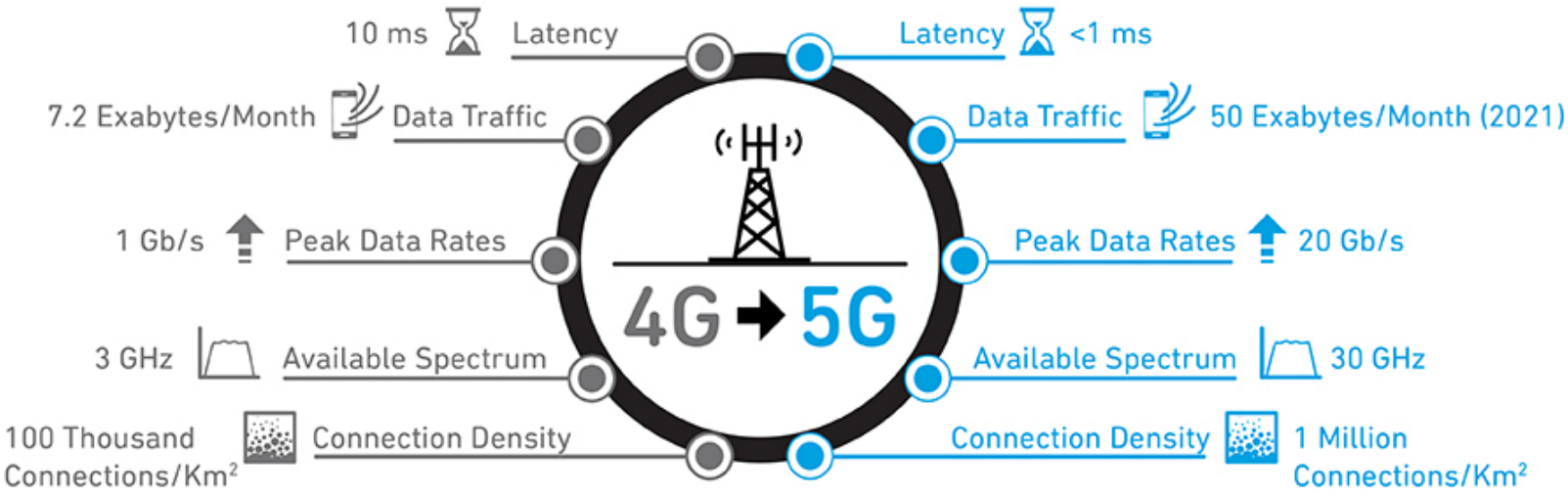
Overview of 5G Antenna

Evolution of 4G to 5G：



All in all, the quality of user experience is the most important issue, which requires more sites, bands and advanced technologies such as massive MiMo.

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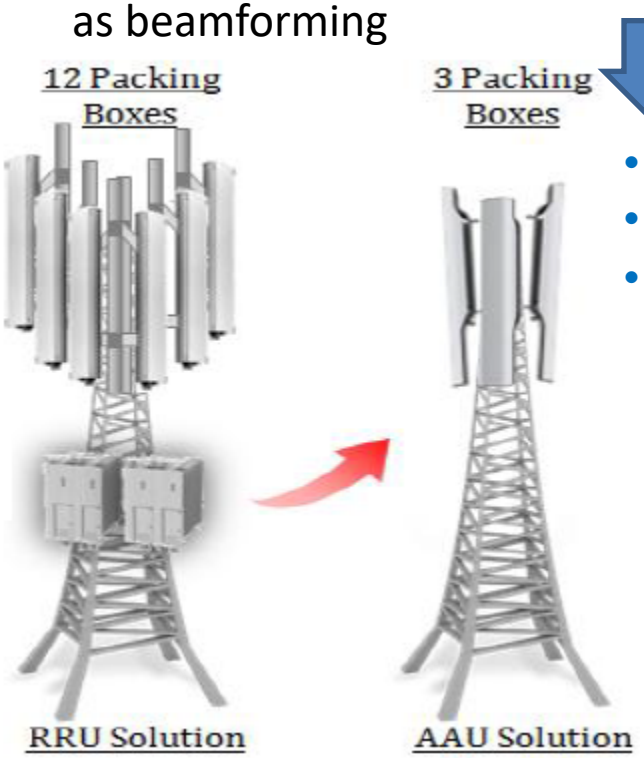
Overview of 5G Antenna

Evolution of RRU to AAU：

Disadvantage of traditional RRU:

- Multiple bands and modes need to rent larger space
- Require more hardware and longer time for new bands or modes
- It's a challenge to support Multiple channels, such as Massive MIMO
- It's hard to support precise coverage technology such as beamforming



- Combine the radio part with the antenna part
- Capable of integrating multiple bands
- Supports more advanced functions such as Massive MIMO and Beamforming

AAU

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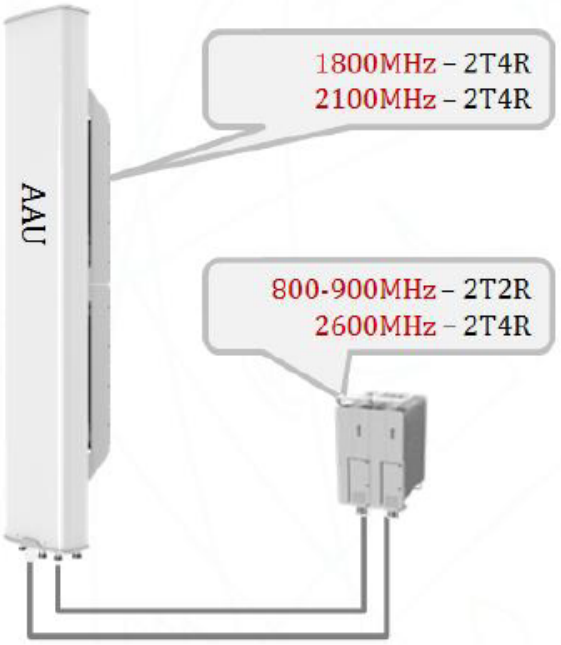
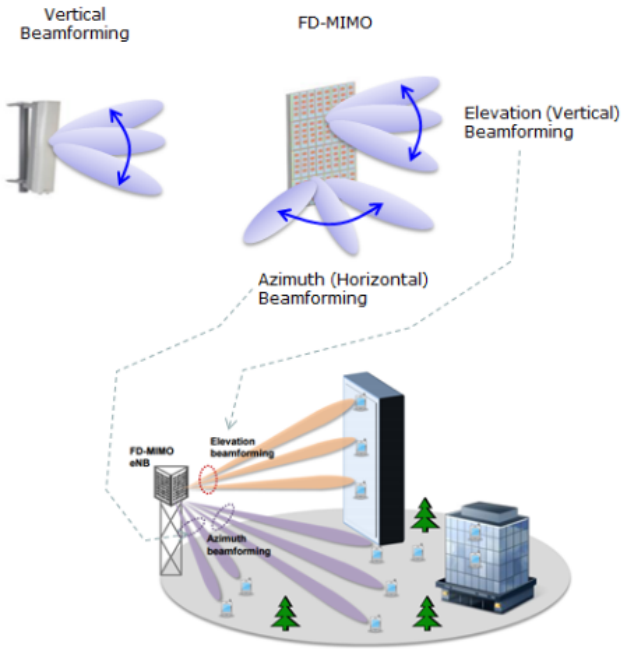
Advantages of AAU：

- Support 5 bands and 3 modes simultaneously
- Extensively simple sites and No Feeder Loss
- Massive MiMo and 3D-beamforming





Advantage of Massive MiMo:

- Improved spectral efficiency and network capacity for higher throughput
- Stronger signal and reduction of interference for better coverage

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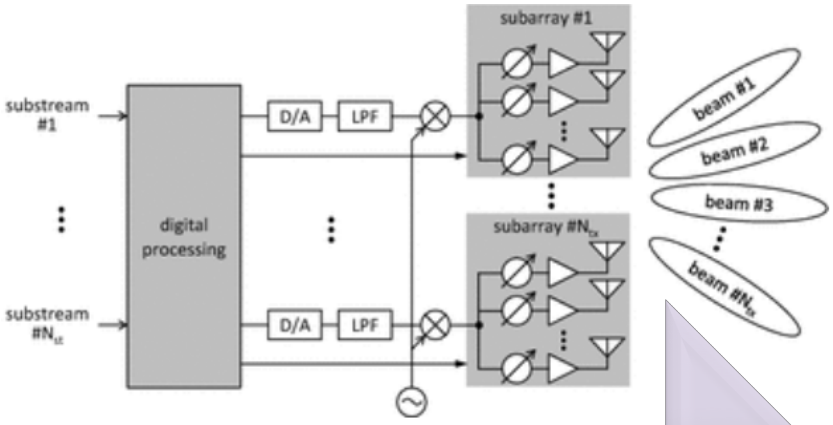
Test of 5G Antenna

Test challenges：



Conducted test for 4G base station

Transceiver frontends integrated with antenna array

RF output ports no longer accessible

Fiber interface input ports for digital IQ data

Over-The-Air (OTA) testing for massive MiMo

OTA test challenges:

- Key challenge is how to obtain the phase information if the input signal into the AUT is unknown
- Test antennas must be equal or greater than the number of antenna array elements of AUT
- Test facility must provide the physical dimensions to provide adequate distance between the DUT and the OTA antennas

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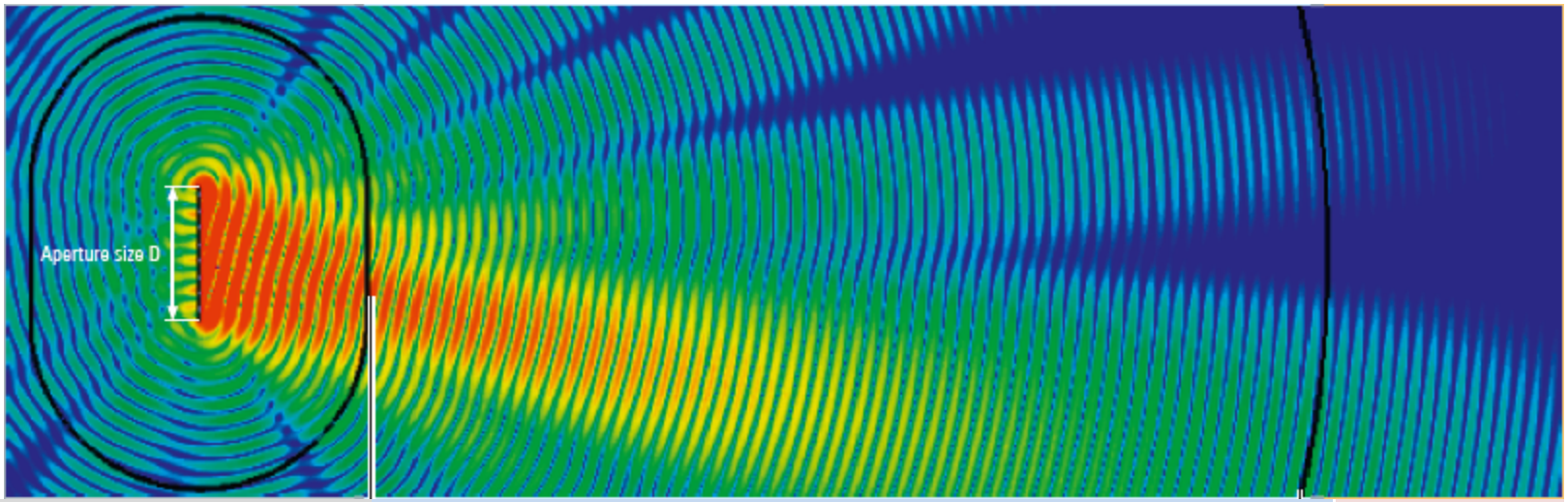
Test of 5G Antenna

Test methods of 5G OTA：



Reactive near-field region | Radiated near-field region (requires phase and magnitude measurement) | Far-field region (requires magnitude measurement only)

Far-field measurements:

- Fast and simple and provide higher measurement reliability
- But path loss is higher and the test setup is larger with increasing DUT size and higher frequencies
- The costs of building such enormous anechoic chamber to accommodate test site requirement are extremely prohibitive

Near-field measurements:

- Compact but complex, time-consuming and have high uncertainty

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Test of 5G Antenna

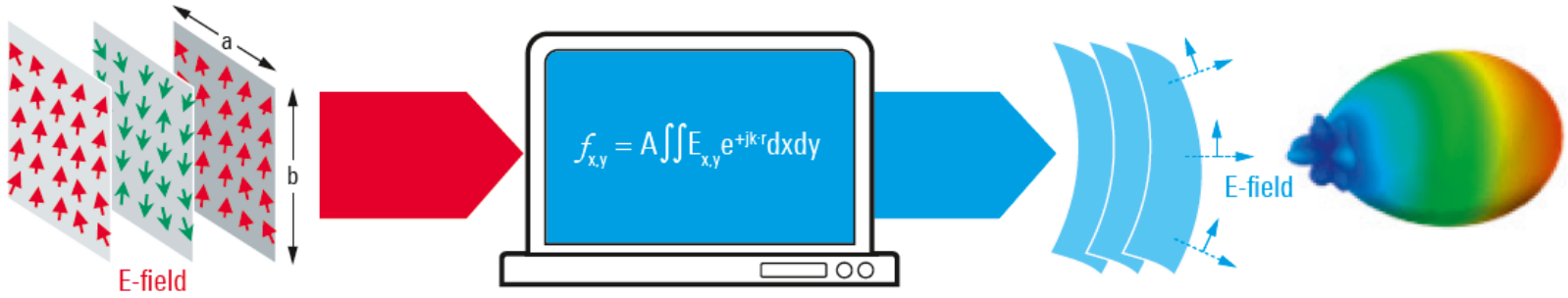
Test methods of 5G OTA：

Far-field measurements at near-field distances:

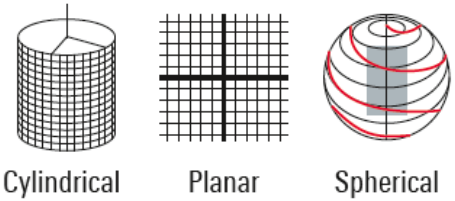
Software based near-field to far-field transformation

Fourier transform – requires phase and magnitude measurement

Complex wave: phase and magnitude measurement Fourier transform: software based Far field: generated



Near-field (E-field) surface measurement methods



This method is generally not suitable for metrics such as EVM and ACLR due to their time dependencies.

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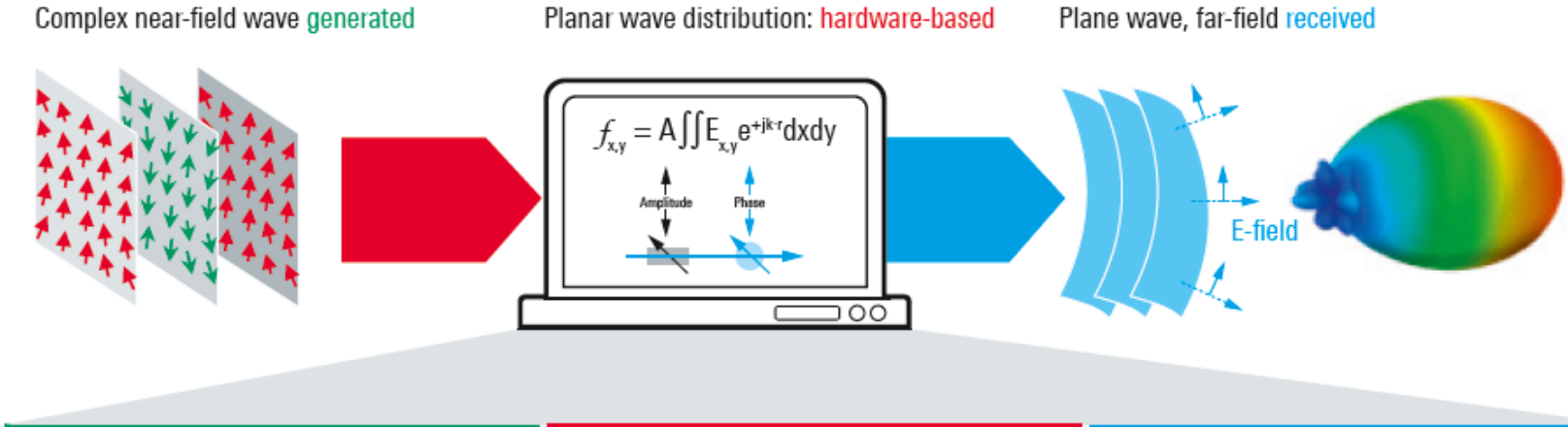
Test of 5G Antenna

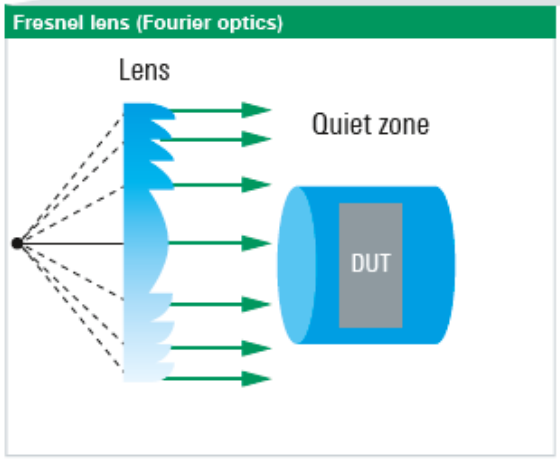
Test methods of 5G OTA：

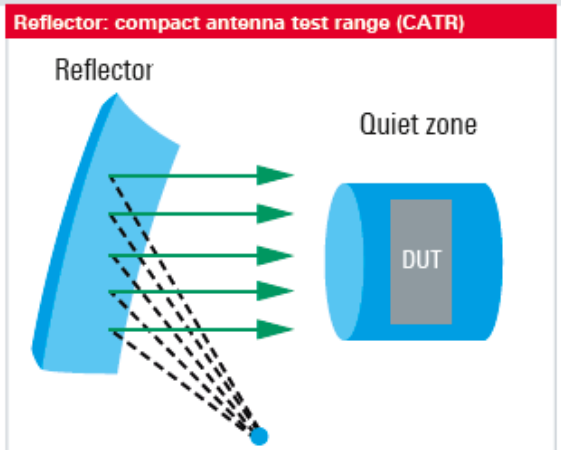
Far-field measurements at near-field distances:

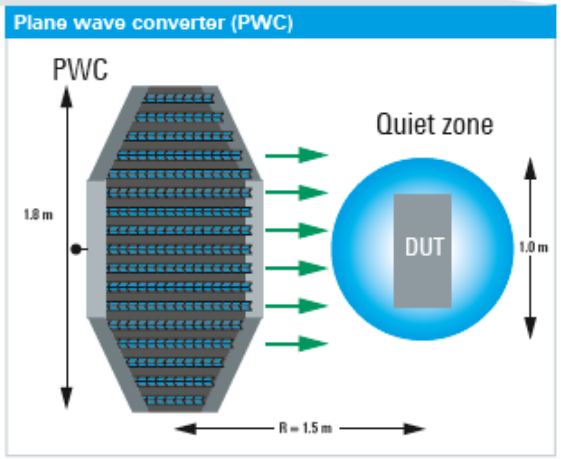
Hardware based near-field to far-field transformation

Planar wave distribution – indirect far-field (IFF)









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Test of 5G Antenna

Test methods of 5G OTA：

➢ Test parameters

Radiated transmit test items	Evaluate methods
Radiated transmit power	EIRP
Out base station output power	TRP
OTA output power dynamics	OTA RE power control dynamic range
	OTA total power dynamic range
OTA transmit ON/OFF power	Transmitter OFF power
	OTA transient period
OTA transmitted signal quality	OTA frequency error
	OTA modulation quality
	OTA time alignment error
OTA unwanted emissions	OTA occupied bandwidth
	OTA Adjacent Channel Leakage Power Ratio (ACLR)
	OTA transmitter spurious emissions
OTA transmitter intermodulation	TRP

Radiated receive test items	Evaluate methods
OTA sensitivity	EIS
Out reference sensitivity level	EIS reference
OTA dynamic range	Throughput
OTA in-band selectivity and blocking	EIS refsens
	Throughput
OTA out-of-band blocking	Throughput
	EIS
OTA receiver spurious emissions	TRP
OTA receiver intermodulation	EIS refsens

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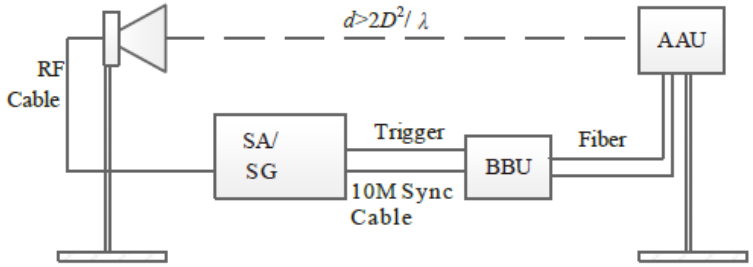
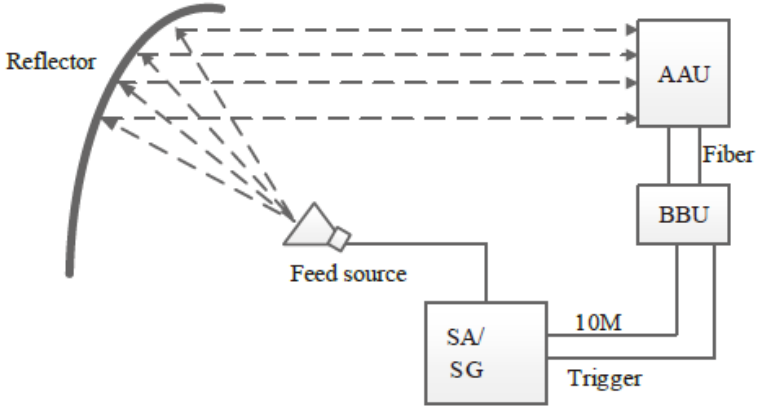
Test of 5G Antenna

Test methods of 5G OTA：

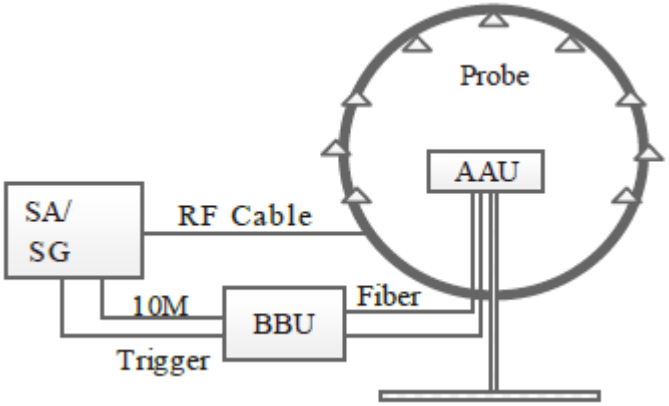
➢ Test architectures



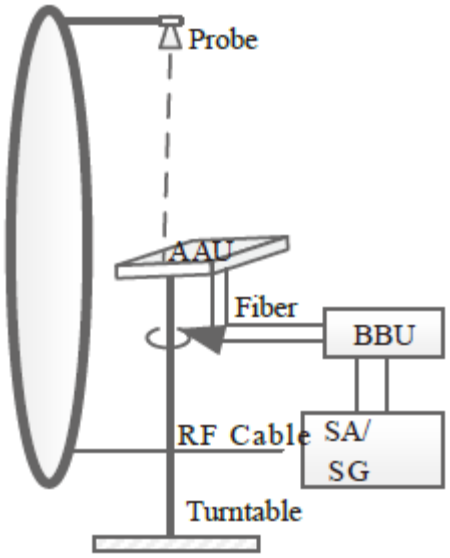
Far-field test system



Single reflector compact antenna test range



Multi-probe spherical near field test system



Single-probe near field test system

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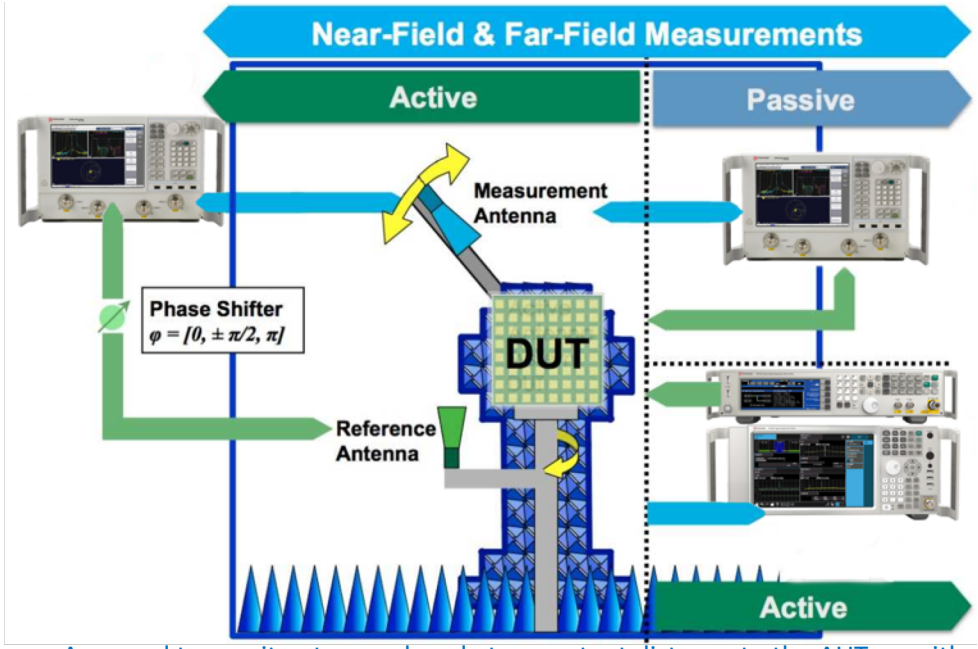
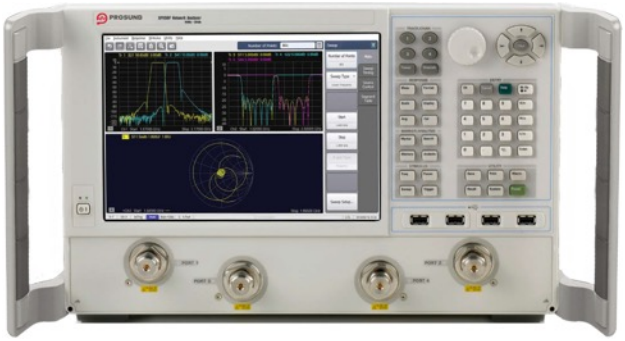
Test of 5G Antenna

Test methods of 5G OTA：

➢ A typical test system architecture



A second transmit antenna placed at a constant distance to the AUT an with known input phase as a reference antenna to determine the phase of AUT



SP800P Vector Network Analyzer

SP900P Signal Analyzer

SP200V Vector Signal Generator

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References

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THANK YOU!

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